RECONSTRUCTION OF FEMUR LENGTH FROM ITS FRAGMENTS

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CERTIFICATE

This is to certify that this dissertation entitled **"RECONSTRUCTION OF FEMUR LENGTH FROM ITS FRAGMENTS"** submitted by Dr.Magendran appearing for M.D. Forensic Medicine Branch XIV Degree Examination in April 2010, is a bonafide record of work done by him under my supervision in partial fulfillment of the regulations of the Tamil Nadu Dr. M.G.R. Medical University, Chennai.

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CONTENTS

INTRODUCTION

RECONSTRUCTION OF FEMUR LENGTH FROM ITS FRAGMENTS

Introduction

All the human beings occupying this globe belong to the same species i.e. Homo sapiens. No two individuals are exactly alike in all their measurable traits, even genetically identical twins (monozygotic) differ in some respects. These traits tend to undergo change in varying degrees from birth to death, in health and disease. Since skeletal development is influenced by a number of factors producing differences in skeletal proportions between different geographical areas, it is desirable to have some means of giving quantitative expression to variations which such traits exhibit.[(1)]

Identification is the recognition of an individual by means of various physical features and biological parameters, which are unique to each individual. There are various established parameters for identification of the individual. These are external features (such as birth marks, scars, tattoo marks, occupational marks, malformations), personal features (such as clothing, speech, handwriting, habits), assessment of age and sex, race and stature, anthropometric measurements, finger prints, foot prints, DNA profiling. The question of identification arises in everyday medico legal practice in civil and criminal cases.

The identity of a dead body may be destroyed by the following causes:

- Purposive removal of the identifying features e.g. Finger prints, tattoo marks, scars, moles, teeth, hair etc.
- Animals e.g., rats, dogs, jackals, hyenas and birds, when body is exposed in an open place.
- Burning or incineration
- Advanced putrefaction
- Chemical destruction of the body in corrosives acids or alkalis
- Dismemberment by moving vehicles like trains or machineries
- Bomb explosions
- Many a times, the exhumed bodies are in fragmented condition.
- Mass disasters e.g. Plane crashes (Mangalore plane crash killing at least 160 people, May 2010), earth quakes etc
- Deliberate mutilation of dead bodies for destroying evidence as seen in recent Nithari serial murder in Noida, Uttar Pradesh, India in the year 2006.

Thus in many conditions forensic investigators have an uphill task to analyze whatever skeletal remains are found and draw inferences of biological and medicolegal importance [2, 3, 4].

I reiterate that proper analysis of the skeletal remains includes determination of the species, races, sex and the **stature** of the individual as well as the possible cause of death and time since death. [3,4,5,6]. Determination of some of these parameters requires the presence of one or more complete long bones, a condition that frequently eludes the investigator.

The primary goal of forensic anthropology is the identification of individuals who are no longer recognizable. The anthropological assessment includes both the identification of the physical characteristics and cause and manner of death from the skeleton. [7]

There are various ways to estimate stature from bones but the easiest and the reliable method is by regression analysis [7, 8]. In the past, scientists have used each and every bone of the human skeleton right from femur to metacarpals in estimation of stature. They all have reached a common conclusion that stature can be estimated with great accuracy even from the smallest bone, although, they have encountered a small error of estimate in their studies.

In humans, femur is the longest and largest bone [9, 10,11].It is also one of the strongest bones in the body. Femur is one of the bones most commonly recovered from aviation accidents, as it is large, durable bone protected by both large amounts of soft tissues and the seat and harness mechanisms of the aircraft.

It is the bone, which has been studied extensively. By studying the femur, one can get fair idea about the age, sex, stature and sometimes the race of the individual. This with other corroboratory evidences would be essential in the identification the deceased.

From the results of all previous studies, the femur in the intact state is one of the bones with highest correlation with stature. It has also been shown to yield the best accuracy in the estimation of stature for any individual skeletal element.

However, the femur is not always recovered intact in forensic cases thereby rendering the equations derived from the whole bone inappropriate for analysis. This has necessitated the derivation of regression equations for estimating the length of femur, from the fragments of femur.

In this study, I will be undertaking anthropometric assessment of length of femur and attempting to relate the various segments of femur to its full length. This study is an effort to derive regression equations for the reconstruction of the length of the femur from it fragmentary remains, based on its metric evaluation.

REVIEW OF LITERATURE

Review of literature

Forensic anthropology according to Mehmet Yasar Iscan is best conceptualized more broadly as ‘a field of forensic assessment of human skeletonised remains and their environment’.[7]

The two most commonly used methods in forensic anthropology are the metric and the morphological assessment under anthropometry and anthroposcopy respectively [12].

Anthropometry means the technique of expressing quantitatively the form of the human body. In other words, anthropometry means the measurement of human beings, whether living or dead or on skeletal material. [1]

Anthropometry is often viewed as a traditional and perhaps the basic tool of biological anthropology, but it has a long tradition of use in forensic sciences and it is finding increased use in medical sciences especially in the discipline of forensic medicine. It is highly objective and reliable in the hands of trained anthropometrists.

Anthropometric characteristics have direct relationship with race, sex, age and stature of an individual and these factors are intimately linked with each other and are manifestation of the internal structure and tissue components which in turn, are influenced by environmental and genetic factors. Anthropometric data are believed to be objective and they allow the forensic examiner to go beyond subjective assessments such as ‘similar' or ‘different'. With measurement data, the examiner is able to quantify the degree of difference or similarity and state how much confidence can be placed in this interpretation [12]

Anthropometry can be subdivided into (i) somatometry including cephalometry and (ii) osteometry including craniometry.

(i) Somatometry[1]

It is the measurement of the living body and cadaver including head and face. Somatometry is considered as a major tool in the study of human biological variability including morphological variation.

(ii) Osteometry[1]

It includes the measurements of the skeleton and its parts i.e. the measurements of the bones including skull. It is defined as a technique to take measurements on the skeletal material. Through this technique, a forensic scientist can study variation in bony skeleton of different populations of the world. The technique has been successfully used in the estimation of stature, age, sex and race in forensic and legal sciences. These four parameters i.e. Race, sex, age and stature are considered as the “big fours” of forensic anthropology.

Various studies have been conducted and are in progress in many parts of the world in this regard. Estimation of the stature is an important aspect of medicolegal investigation. Reconstructing stature from the skeletal remains dates to the early 1800s. This is reiterated by the fact that stature estimation from various skeletal remains has been an area of vital interest to research workers for more than hundred years now.[7] Stature provides one aspect of an individual physiognomy and one piece of critical information that may be an aid in individual identification. The introduction of regression formulae developed in modern population has enhanced the accuracy of estimation, especially when multiple long bones are available for the same individual. The authors of purely historical importance in this regard include Orfila, Langer, Toldt, Toinard and Beddoe.

Work by a nineteenth century anatomist, Thomas Dwight, marks the most distinct origins of the field. Holding the title of “the father of forensic anthropology,” Dwight was an anatomist interested not only in human skeletal biology but more specifically in human skeletal variation (Stewart 1978). Dwight, and those who followed after, concerned themselves with the documentation of variation between individuals, but not the identification of unknown individuals. It was this shift from basic anatomy to individualized study of variation, nevertheless, that gives the research a decidedly anthropological nature (Rhine 1998).

It was Rollet in the year 1888, who published the earliest formal statural tables, using humerus, radius, ulna, femur, tibia and fibula of 50 male & 50 female French cadavers.In 1892 and 1893, Manouvrier reassessed Rollets data and further refined the statural tables(7)Later in the year 1899, Pearson, developed the regression formula using Rollets data and laid down basic rules for stature reconstruction (7)

Hrdlicka, in the year 1898-1902 measured assorted long bones of dissecting room population and calculated long bone /stature ratios. Specifically we may note that the humerus/ stature index and the femur / stature index [7]. The researches of Trotter M and Glesser G C, Dupertuis C W and Hadden J A, have laid benchmark for reconstruction of stature estimation from long bones. [13, 14, 15]

In India panoptic research on stature estimation from skeletal remains have been done[16] some of the research for calculating stature from long bones on different populations include Kler and Butt, 1922 ; Pan, 1924; Nat, 1931; Siddique and Shah, 1944; Singh and Shoal, 1952; Jit and Singh, 1956; Lal and Lala, 1972; Kolte and Bansal, 1974; Kate and Majumdar, 1976; Mysorekar Et Al , 1980, 1982 and 1984; Badkur, 1985; Shroff and Fakruddin, 1986, Nath Et Al 1987; Badkur and Nath, 1989; Rao Et Al, 1989; Nath and Badkur, 1990; Kler Et Al, 1992; Kler, 1994; Kler and Kaur[16, 17,18,19]

From these researches, it was established that the stature could be estimated with long bones either by using multiplication factor or with the application of regression formulae [20]

Bhavna et al., 2006; Rani et al., 2006 conducted a study constituting 503 male Shia muslims of Delhi, in the age range of 20 to 40 years for the of stature on the basis of measurements the lower limb. [21]

Linear regression equations for estimation of stature from different body dimensions among male Shia Muslims of Delhi

1. S = 84.74 + 2.27 (tibia) ± 3.67
2. S = 79.35 + 2.29 (fibula) ± 3.71
3. S = 77.99 + 2.15 (femur) ± 3.80

To summarize, estimation of stature presence of one or more long bones, a condition too often uncommon as cited in the introduction. So to overcome this hurdle is to estimate the total length of the long bone from the fragments and later employ them in statural formulae to get reasonably accurate stature. [22, 23, 24].

First attempt was done by Muller [7] who in the year 1935 tried to establish a technique that would permit stature estimation from long bone fragments. The first work was carried out on 50 radii, 100 humeri and 100 tibiae. Basically she calculated per-cent total length of various sections of long bones. Thus Mullers paper demonstrated the correlations between portions of long bones and their total length are feasible. She did not include femur in her study as she feared that the variation of the joint angle would hinder the results. Nonetheless Trotter and Glesser (1958) Genvoes (1967) have proved reasonably well that femur good correlation with stature

Genry Steele and Thomas W. Mckern from the University of Kansas selected the femur, tibia, humerus to tackle the same problem of estimation of stature; from the fragmentary long bones. They criticized the exclusion of femur from Muller's selection because the femur is regarded as the singular bone with one of the highest correlations with stature. They replaced the radius with femur in their study but used the method of delineating a long bone into sections as suggested by Muller.

Steele and Mc Kern (1969), and Steele (1970) outlined a number of landmarks establishing four segments in the femur, four in the humerus and five in the tibia.

The landmarks selected by them for the femur were

1. most proximal point of head
2. midpoint of lesser trochanter
3. most proximal extension of the popliteal surface at point where the medial and lateral supracondylar lines become parallel below

linea aspera

4. most proximal point of the intercondylar surface
5. most distal point of the medial condyle

V R Mysorekar et al (1980 to 1984) proposed estimation of stature form parts of femur , tibia, humerus , radius and ulna (18,19) In case of femur, a reliable regression equation to give the total length of femur from the distal end fragment (adductor tubercle to distal end of femur) were derived.

Schroff A G, Pansee A A and Diwan C V (1999) did a similar research on femur in Aurangabadh , India and derived regression equations to calculate the total length of femur. The landmarks for demarcating the segments of the femur in their study were

1. the most proximal point on upper end of femur
2. Lower border of lesser trochanter
3. Apex of the popliteal surface
4. Adductor tubercle
5. The distal most point of the lower end of femur

Over a period of time, when these data were actually put in practice, many shortcomings were noticed. Most practicing forensic anthropologists faced many practical difficulties in locating precise anatomical landmarks in fragmentary remains of bones [22]

The techniques for delineating segments of the bone as suggested by Steele and McKern were not easily reproducible. Thus the crucial parameters necessary for determination of the total length were flawed. Stature thus estimated was significantly inaccurate and the medicolegal importance was significantly eroded.This was envisioned by none other than Steele himself.[22]

So alternate, pragmatic and holistic approach to this problem was required.

In the year 1989, Tal Simmons, Richard l Jantz and William M Bass proposed a new revised method which was published in the journal of forensic sciences. This attempted to overwhelm the pitfalls in Steele's method by using standard, clearly defined measurements taken on the proximal, distal and mid-shaft region of the femora.

The parameters considered were:

1. Maximum femoral length

2. Vertical diameter of the femoral head (VHD)
3. Vertical diameter of the femoral neck (VND)
4. Upper breadth of the femur (VHA)
5. Transverse diameter of the mid- shaft (WSD)
6. Bicondylar breadth (BCB)
7. Epicondylar breadth (FDL)
8. Medial condylar height (MCH)
9. Lateral condylar height (LCH)

Thus they tried to overcome the difficulties which plagued earlier approach by using clearly defined measurements. Most of these measurements were already in use by physical anthropologists. The sample measured in this study obtained from the Terry anatomical collections housed at Smithsonian institutions, National museum of Natural History located in Washington D C. Since Terry's collections contain accurate data for age, sex, race, and cadaver stature of the individuals, they formulated regression equations for estimating femur length and stature directly.

In his study, all the measurements showed statistically lower mean values in males than in females, confirming the sexual dimorphism of femoral dimensions as reported in earlier study by Steyn and Iscan.

It appeared in his study that overall best predictor in males would be VHA (upper breadth of femur), however in females several other measurements are more highly correlated.

In white females, LCH (lateral condylar height) showed the highest correlation (0.665). In black females, both LCH (lateral condylar height) and VHD (vertical height of head) showed higher correlation (0.585). In general, a correlation does not exceed 0.65 except LCH in white females.

In the early part of 2008, Mubarak Ariyo Bidmos studied estimation stature and femoral length using fragments of femur in Indigenous South Africans (ISA) and South Africans of European Descent (SAED) [23, 24]. His study was similar to Simmons method. The skeletal elements were obtained from Raymond A .Dart collection of human skeletons housed in the school of anatomical sciences, University of Witwatersrand, Johannesburg, South Africa.

The anatomical parameters considered were

1. Maximum length of femur – FML
2. Upper epicondylar breadth or upper breadth of femur – UEpL
3. Vertical neck diameter – VND
4. Epicondylar breadth – EpB
5. Bicondylar breadth – BCB
6. Medial condyle length – MCL
7. Lateral condyle length – LCL

He derived equations both for the estimation for the stature and maximum femoral length form the fragmentary femora.

In his study, Mubarak Ariyo Bidmos showed that among the indigenous South African population, males showed higher mean values compared to females in all femoral measurements. Males showed a moderate correlation between individual variables, while a higher degree of correlation as obtained in the female sample.

In males, measurements of the distal end of femur (MCL) consistently showed the best correlation with maximum length of femur. However the UEpL, one of the measurements on the proximal aspects of femur, showed the highest correlation with the maximum length of femur in females and displayed the second best correlation in males.

Regression equations for the estimation of maximum length of the femur from various combinations of femoral variables were derived. Equations derived for the female samples presented with a higher correlation (0.80 – 0.83) compared with that obtained for male samples (0.63 – 0.75). The standard error of estimate obtained for the estimation the femur from its fragments ranged from 1.46 to 1.69cm for males and 1.48 – 1.54cm in females.

Among the South African population of European descent (SAED), males showed higher mean values compared to females in all femoral measurements. Females showed the highest correlation coefficients compared to males.

Measurements of the distal end of femur (FDL, MCL, LCL and BCB) consistently showed the best correlation with maximum length of femur in females. However the upper breadth of femur (UEpl), one of the measurements on the proximal aspects of femur, showed the highest correlation with the maximum length of femur in males and lateral condylar length displayed the second best correlation. In general, measurements of the distal end of femur displayed the highest correlation in Bidmos study, which is in contrast the result of Simmons study.

Regression equations for the estimation of maximum length of the femur from various combinations of femoral variables were derived. Equations derived for the female samples presented with a higher correlation (0.78 – 0.83) compared with that obtained for male samples (0.61 – 0.66). Regression equations presented with slightly higher standard error of estimate for males compared to those obtained for females.

In this study, the length of femur is determined from its fragments by combining the methods of Simmons et al and that of Bidmos.

ANATOMY OF FEMUR

Anatomy of femur (figure 1)**:**

The word femur is latin for thigh. Theoretically in strict usage, femur bone is more proper than femur, as in classical latin femur means "thigh", and os femoris means "the bone within it".

In medical latin its genitive is always femoris, but in classical latin its genitive is often feminis

The femur is the longest and one of the strongest bones in the skeleton and can support up to 30 times the weight of an adult. The femur, like other long bones, is divisible into a body and two extremities.

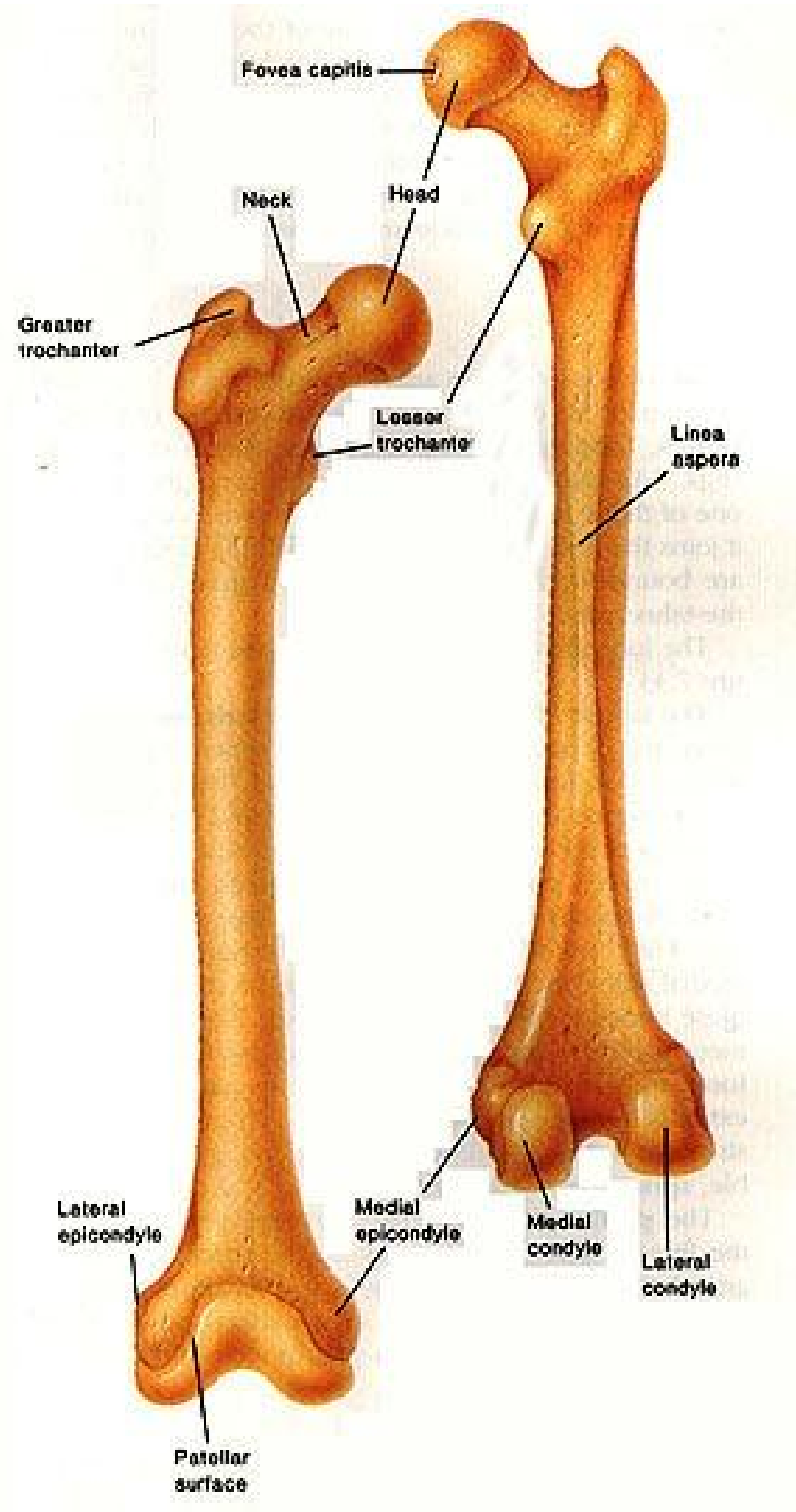
The upper extremity:

The upper extremity has a head, a neck, a greater and a lesser trochanter.

The head (caput femoris):

The head is globular and forms rather more than a sphere, is directed medially upwards, and a little forwards, the greater part of its convexity is being above and in front of its surface is smooth, coated with cartilage in the fresh state, except over an ovoid depression, the fovea capitis femoris, which is situated a little below and behind the centre of the head, and gives attachment to the ligamentum teres.

Figure-1



Fovea capitis
Neck
Head
Greater trochanter
Lesser trochante
Linea aspera
Lateral epicondyle
Medial epicondyle
Medial condyle
Lateral condyle
Patellar surface

The neck (collum femoris) :

The neck is flattened pyramidal process of bone, connecting the head with the body and forming with the latter a wide angle. The angle is widest in infancy, and becomes lessened during growth, so that at puberty it forms a gentle with the axis of the body of the bone. In the adult, the neck forms an angle of 125˙ with the body, but this varies in inverse proportion with the growth of the pelvis and the stature. In the females, in consequence of the increased width of the pelvis, the neck of the femur forms more nearly a right angle with the body than does in the male. The angle decreases during the period of growth, but after full growth has been attained it does not usually undergo any change, even in old age; it varies considerably in different persons of the same age. It is smaller in short than in long bones, and when the pelvis is wide. In addition to projecting upward and medial ward from the body of the femur the neck also projects somewhat forward; the amount of this forward projection is extremely variable.

The trochanters:

The trochanters are prominent processes, which afford leverage to the muscles that rotate the thighs on its axis. They are two in number, the greater and the lesser.

The greater trochanter (trochanter major; great trochanter) is a large irregular, quadrilateral eminence, situated at the junction of the neck with the upper part of the body. It is directed a little lateral ward and backward; and in the adult, is about 1 cm, lower than the head. It has two surfaces and four borders. The lateral surface, quadrilateral in form, is broad, rough, convex and marked by diagonal impression, which extends from the posterosuperior to the anteroinferior angle, serves for the insertion of gluteus medius.

The medial surface is of much less extent than the lateral surface, presents at its base a deep depression; the trochanteric fossa; for the insertion of the tendon of obturator externus, and above and in fronts of this an impression for the insertion of the tendon of the obturator internus and gemmelli. The superior border is free; it is thick and irregular, and marked near the centre an impression for the insertion of pyriformis. The inferior border corresponds to the junction of the base of the trochanter with the lateral surface of the body; it is marked by a rough, prominent, slightly curved ridge, which gives origin to the upper part of vastus lateralis. The anterior border is prominent and somewhat irregular; it affords insertion at its lateral part to the gluteus maximus. The posterior border is very prominent appears as a free, rounded edge, which bounds the back part of the trochanteric fossa.

The lesser trochanter (trochanter minor; small trochanter) is a conical eminence. It varies in size in different subjects and it projects from the back & lower part of the base of the neck.

The body or the shaft:

The body, almost cylindrical in form, broadest and somewhat flattened from before backward below. It is slightly arched, so as to be convex in front, and concave behind, where it is strengthened by a prominent ridge, the linea aspera. It presents for examination three borders, separating three surfaces. Of the three borders the linea aspera is posterior, one is medial and the other lateral.

The lower extremity (distal extremity)

The lower extremity, larger than the upper, is some what cuboid in form, but its transverse diameter is greater than the anteroposterior diameter, it consists of two oblong eminences the condyles. In the front, the condyles are, slightly prominent, and are separated from one another by a smooth shallow articular depression called the patellar surface; behind, they project considerably, and the interval between them forms deep notch, the intercondyloid fossa. The lateral condyle is more prominent and is broader both in its anteroposterior and transverse diameters, the medial condyle is longer and, when the femur is held with its body perpendicular, projects to a lower level. When, however, the femur in its natural oblique position the lower surfaces of the two condyles lie practically in the same horizontal plane.

The condyles are not quite parallel with one another. The long axis of the lateral condyle is almost directly anteroposterior, but that of the medial condyle runs backward and medially. Their opposed surfaces are small, rough, and concave, and form the walls of inter condyloid fossa. This fossa is limited above by a ridge, the intercondyloid line, and below by the central part of the posterior margin of the patellar surface. Each condyle is surmounted by an elevation, the epicondyle. The medial epicondyle is a large convex eminence to which the tibial collateral ligament is attached. At its upper end, the adductor tubercle and behind it is a rough impression which gives origin to the medial head of gastrocnemius. The lateral epicondyle, smaller and less prominent than the medial gives attachment to the fibular collateral ligament of the knee joint.

Articular surface:

The two condyles are partially covered by a large articular surface which is divisible into patellar and tibial parts. The patellar surface covers the anterior surface of both two condyles and extends more on the lateral condyle than on the medial. The part of the surface over the lateral condyle is short and straight anteroposteriorly, the part of the medial condyle is longer and is curved with its convexity directed medially.

AIM OF THE STUDY

Aim of the Study

Objectives of the study

- To correlate various measurements of fragments of femur with its maximum length,
- To assess the feasibility of estimation of maximum femoral length from metric study of its fragments
- To derive regression equations for calculating maximum length of femur from its fragments.
- To compare the results obtained with similar studies

MATERIALS AND METHODS

Materials & Methods

Period of study: August 2008 to August 2010.

Ethical clearance: obtained**.**

Study design: Descriptive cross sectional study

Collection of samples: The femora for the study were collected from unidentified, unclaimed bodies coming for routine medico legal postmortem examination to the Institute of Forensic Medicine, Chennai-3.

Inclusion criteria:

1. Intact femur from the unidentified, unclaimed bodies cases coming for routine medicolegal postmortem examination

2. Completely ossified femur

Exclusion criteria:

1. Cases below 20 years of age and unossified femur.

2. Cases showing deformed, diseased or fractured femur which will hamper the study of femur length measurement.

Removal of femur:

Removal of femur is done by a long lateral skin incision extending from hip joint to knee joint. The knee joint is exposed by flexing the knee and cutting the quadriceps tendon, the joint capsule, and the cruciate ligaments. The muscular attachments are dissected from the shaft of the femur, starting at the distal end and continuing towards the hip. The capsule of the hip joint is palpated and then incised by flexing and rotating the femur. The femur is dissected out by incising the other ligaments. [(26)] The soft tissues are removed by treating the femur with antiformalin solution.

Preparation of antiformalin solution:

Three litres of antiformalin solution was prepared by mixing 150 grams of sodium carbonate in 250 ml of water, 100 grams of bleaching powder in 750 ml of water and 1000 ml of 15% sodium hydroxide in 1000ml of water. After antiformailin treatment to remove the soft tissues, the bones were washed with water and then air dried in the shade for a period of one week. (Snyder et al)

The maximum length of femur is measured by osteometric board.

Osteometric board (figure 2):

Figure 2

Osteometric boards are measuring devices commonly employed to determine the physical length of long bones in the upper and lower appendages. Theduce less error than hand measurements (Adams and Byrd 2002)

This has a rectangular base with a ruler fixed along one of its long sides. An upright is fixed at one end of the board, and a second one slides along the board. The bone is placed with one of its ends against the fixed upright and the movable upright is brought up to the other end of the bone. The distance between the uprights is the length of the bone.

Other femoral measurements were taken by vernier calipers.

Electronic digital vernier sliding caliper (Figure 3):

Methods:

By using osteometric board and sliding calipers, following measurements (figure 4 & 5) were taken

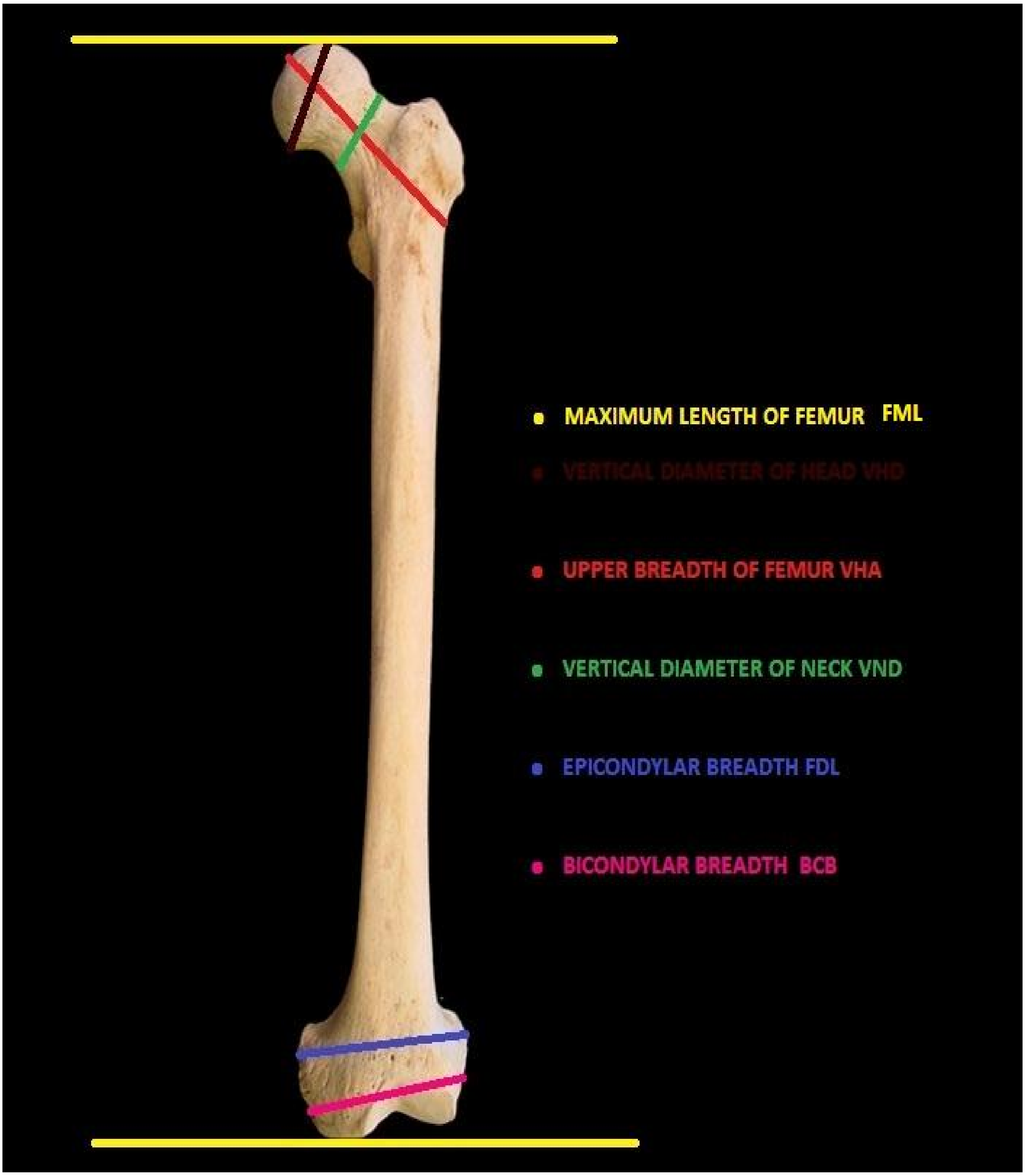
1. Maximum length of femur – FML
2. Vertical diameter of the femoral head - VHD
3. Upper epicondylar breadth or upper breadth of femur – VHA
4. Vertical neck diameter – VND
5. Epicondylar breadth – FDL
6. Bicondylar breadth – BCB
7. Medial condyle length – MCL
8. Lateral condyle length – LCL

All these measurements were taken as per the standards recommended by Brauer [23, 24].

The measurements (VHD, VHA, VND, FDL and BCB) which were used by Simmons et al, were selected because of the ease with which they could be easily reproduced. In addition to these, two other measurements namely medial condylar and lateral condylar lengths (MCL & LCL) were selected because of their high coefficient of reproducibility.[23]

The measurement (1) was measured by osteometric board and other measurements (2-8) were measured by sliding calipers.

Figure 4



MAXIMUM LENGTH OF FEMUR FML
VERTICAL DIAMETER OF HEAD VHD
UPPER BREADTH OF FEMUR VHA
VERTICAL DIAMETER OF NECK VND
EPICONDYLAR BREADTH FDL
BICONDYLAR BREADTH BCB

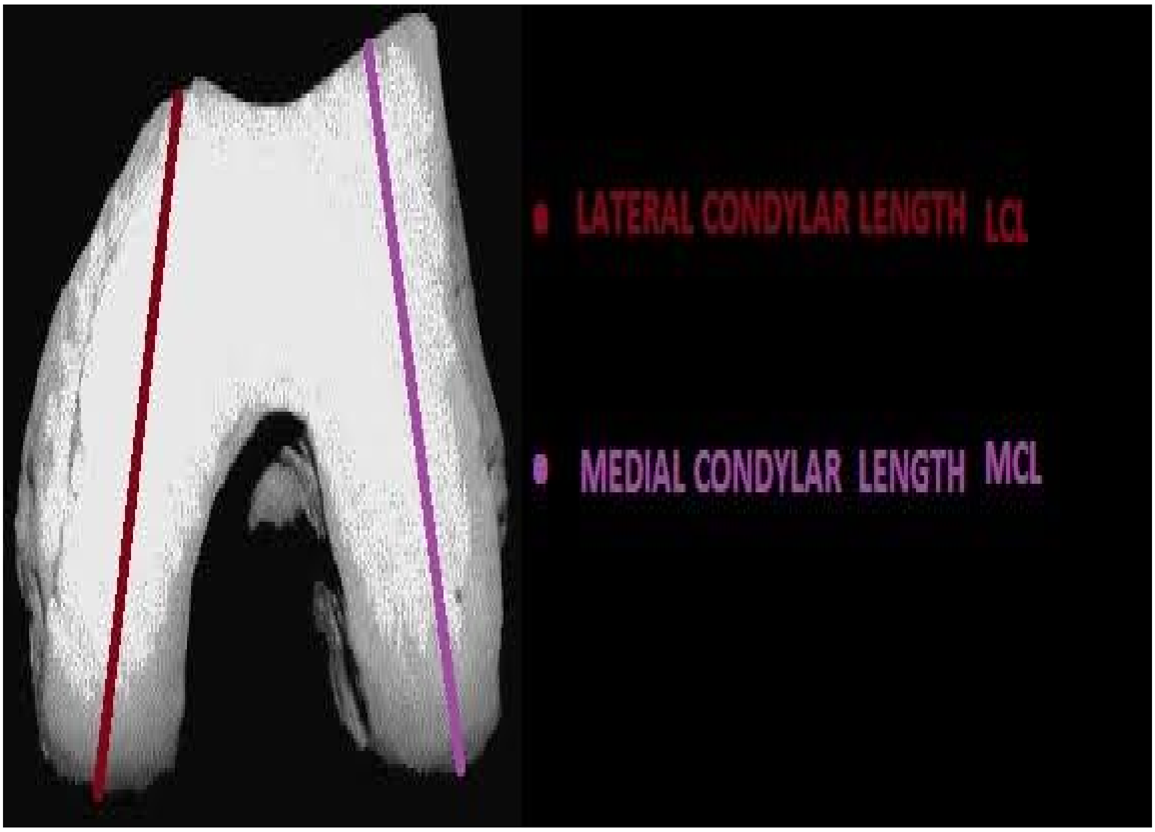


Figure 5

1. Maximum length of femur – FML

The linear distance between the most superior part of the head of the femur and the most inferior part of the medial condyle.

2. Vertical diameter of the femoral head - VHD

The linear distance between the highest and lowest points of the head in the equatorial plane.

3. Upper breadth of femur – VHA

The linear measurement between the most superior point on the fovea capitis to the inferior aspect of the greater trochanter.

4. Vertical neck diameter – VND

The minimum linear distance between the superior and inferior points on the neck of the femur

5. Epicondylar breadth – FDL

The linear distance between the most projected points on the epicondyles. The measurement is taken right angle to the shaft axis.

6. Bicondylar breadth – BCB

The most lateral and posterior projection of the lateral condyle, to the most medial and posterior projection of the medial condyle.

7. Medial condyle length – MCL

The linear distance between the most anterior and the most posterior points on the medial condyle.

8. Lateral condyle length – LCL

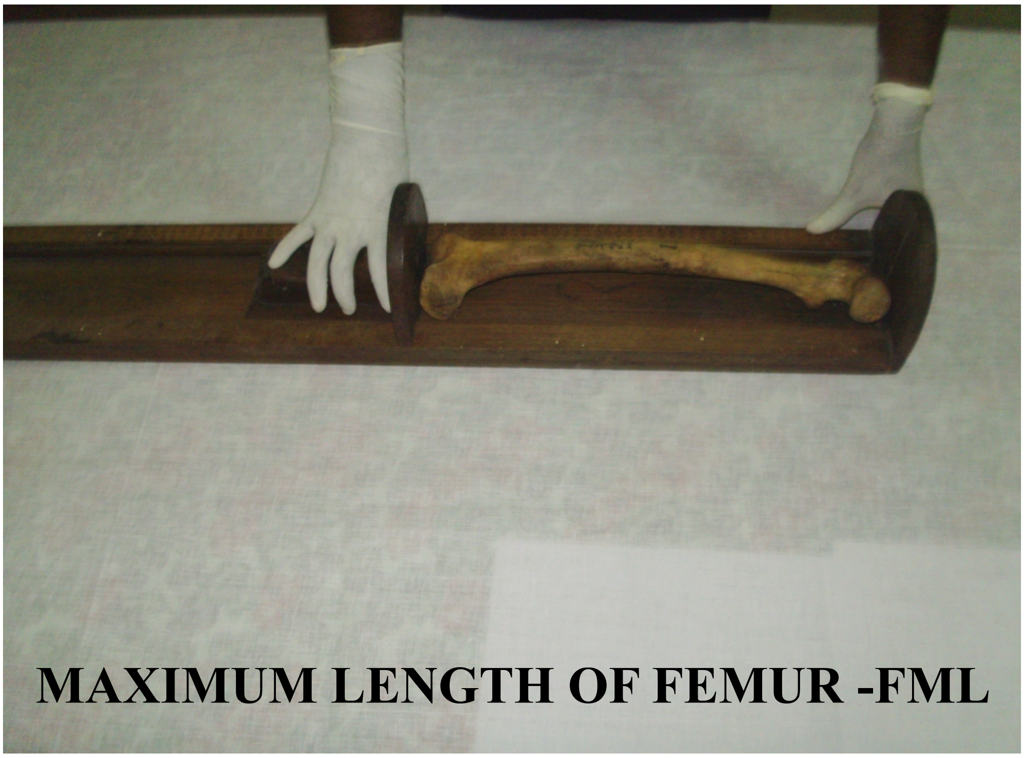
The linear distance on the lateral condyle measured in an anteroposterior direction.

The data were collected and placed into excel sheets, statistical analysis carried out on the male and female groups using SPSS software.

Descriptive statistics including means and standard deviation were obtained for both sexes.

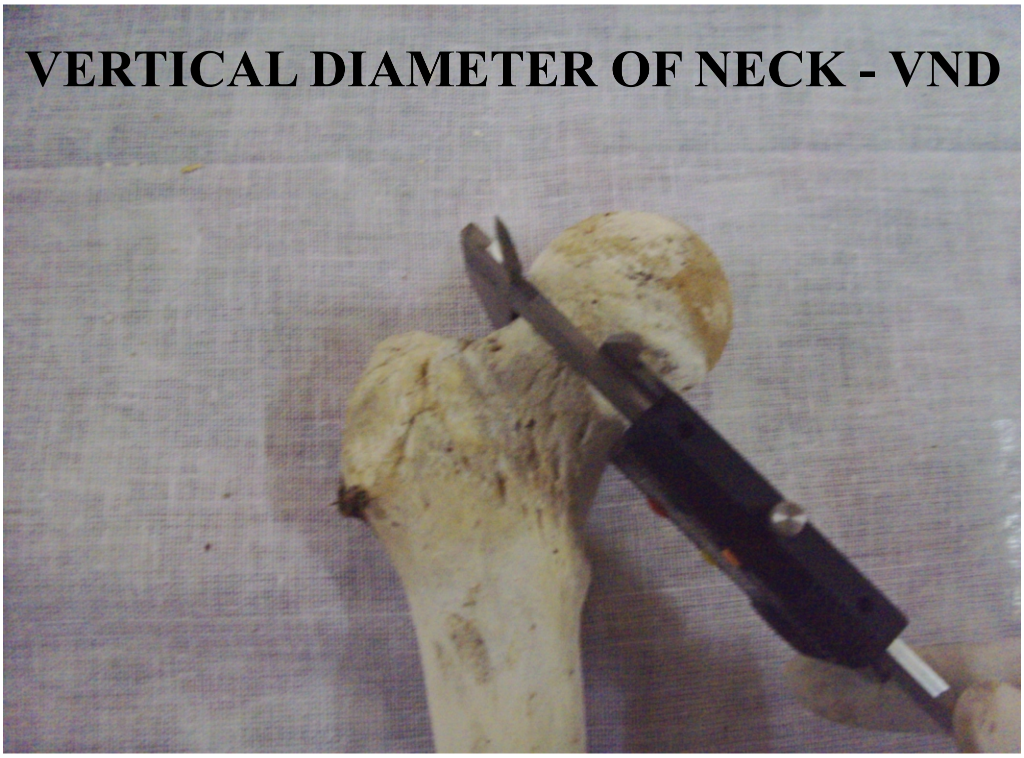
FML was regressed on individual measurements and combination of measurements.

Then, correlation coefficients and standard error of estimate (SEE) were obtained. Regression equations were formulated from these coefficients.

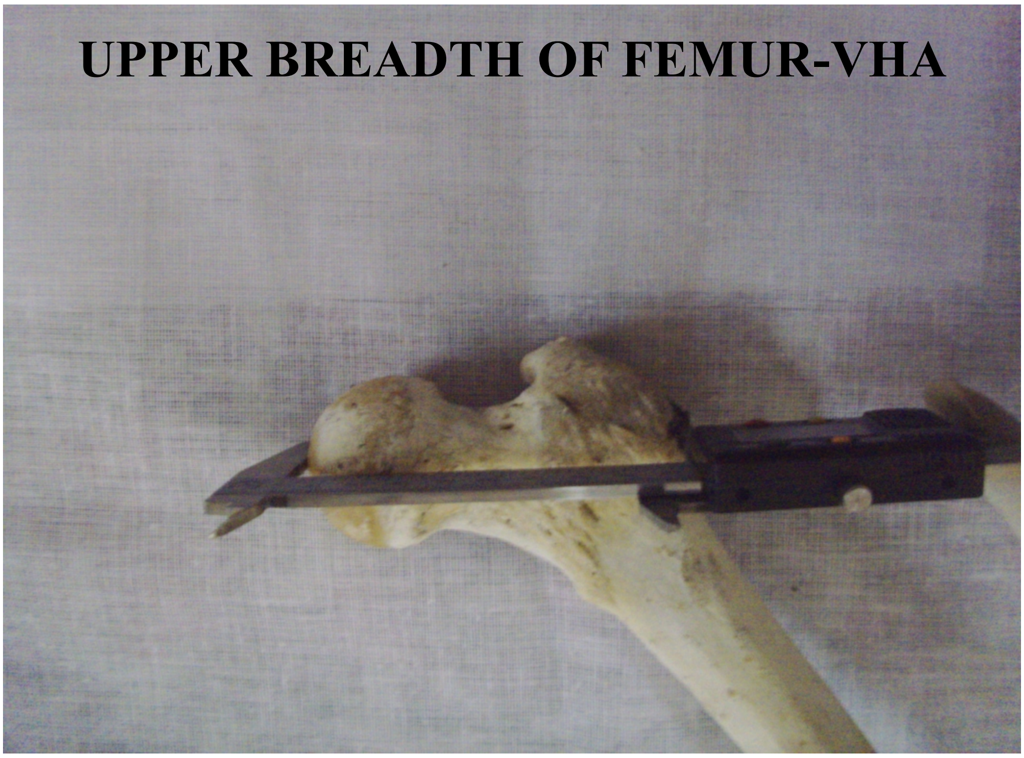


MAXIMUM LENGTH OF FEMUR -FML

VERTICAL DIAMETER OF HEAD - VHD



VERTICAL DIAMETER OF NECK - VND



UPPER BREADTH OF FEMUR-VHA

EPICONDYLAR BREADTH - FDL

BICONDYLAR BREADTH - BCB

LATERAL CONYLAR LENGTH - LCL

MEDIAL CONYLAR LENGTH - MCL

RESULTS

Results

We examined 120 adult femora, consisting of 60 males and 60 females.

The values of FML, VHD, VHA, VND, FDL, BCB, MCL and LCL of 120 femora are showed in the table -1.

The minimum, maximum, mean and the standard deviation of all the measurements were taken from them.

The descriptive statistics of all the femora are shown in table –2,

The descriptive statistics of the male samples are explained in table –3,

Similarly the descriptive statistics of the female samples are detailed in table -4

Table – 2

DESCRIPTIVE STATISTICS OF ALL THE FEMORA

MEASUREMENTS	NO	MINIMUM CM	MAXIMUM CM	MEAN CM	STD. DEVIATION
FML	120	36.4	47.8	42.2	3.0
VHD	120	3.35	5.11	4.2	0.5
VND	120	2.19	3.9	2.9	0.4
VHA	120	7	10.55	8.7	1.0
BCB	120	5.3	8.27	6.7	0.7
FDL	120	5.91	8.47	7.3	0.7
LCL	120	4.9	7.35	5.8	0.6
MCL	120	4.67	7.44	5.7	0.7

FML: MAX. FEMORAL LENGTH　　BCB: BICONDYLAR LENGTH

VHD: VERTICAL DIAMETER OF HEAD　　FDL: EPICONDYLAR LENGTH

VND: VERTICAL DIAMETER OF NECK　　VHA: UPPER BREADTH OF FEMUR

LCL: LATERAL CONDYLAR LENGTH　　MCL: MEDIAL CONDYLAR LENGTH

In both males and females, the maximum length of femur ranged from 36.4 cm to 47.8 cm, with mean of 42.2 cm.

TABLE – 3: DESCRIPTIVE STATISTICS OF MALE FEMORA

MEASUREMENTS	**NO**	**MINIMUM CM**	**MAXIMUM CM**	**MEAN CM**	**STD. DEVIATION**
FML	60	41.2	47.8	44.9	1.5
VHD	60	4.2	5.11	4.6	0.2
VND	60	2.76	3.9	3.2	0.3
VHA	60	8.54	10.55	9.5	0.5
BCB	60	6.23	8.27	7.2	0.5
FDL	60	7.34	8.47	8.0	0.3
LCL	60	5.28	7.35	6.2	0.5
MCL	60	5.35	7.44	6.3	0.5

In males, the maximum length of femur ranged from 41.2 cm to 47.8 cm, with mean of 44.9 cm.

TABLE – 4: DESCRIPTIVE STATISTICS OF FEMALE FEMORA

MEASUREMENTS	**NO**	**MINIMUM CM**	**MAXIMUM CM**	**MEAN CM**	**STD. DEVIATION**
FML	60	36.4	42.6	39.5	1.4
VHD	60	3.35	4.2	3.8	0.2
VND	60	2.19	2.95	2.6	0.2
VHA	60	7	8.76	7.9	0.5
BCB	60	5.3	7.01	6.1	0.3
FDL	60	5.91	7.14	6.6	0.3
LCL	60	4.9	6.27	5.4	0.3
MCL	60	4.67	5.77	5.2	0.3

In contrast to males, females show statistically significant low mean values compared to males in all the measurements.

In females, the maximum length of femur ranged from 36.4 cm to 42.6 cm, with mean of 39.5 cm.

Correlation is a measure of association between two variables. In our case, it is the strength of association of the maximum femoral length with its fragments.

Correlation between the measurements of the fragments of the femur with its maximum length (FML) is scripted in table – 5. They are described under males, females.

TABLE – 5

CORRELATIONS OF MEASUREMENTS OF FRAGMENTS OF FEMUR WITH MAXIMUM LENGTH OF FEMUR (FML)

FRAGMENTS	**FML (MALES)**	**FML (FEMALES)**	**FML (OVERALL)**
VHD	0.618(**)	0.613(**)	0.913(**)
VND	0.709(**)	0.579(**)	0.873(**)
VHA	0.806(**)	0.618(**)	0.927(**)
BCB	0.770(**)	0.257(*)	0.870(**)
FDL	0.811(**)	0.414(**)	0.922(**)
LCL	0.794(**)	0.319(*)	0.844(**)
MCL	0.811(**)	0.627(**)	0.915(**)

** CORRELATION IS SIGNIFICANT AT THE 0.01 LEVEL (2-TAILED)

** CORRELATION IS SIGNIFICANT AT THE 0.05 LEVEL (2-TAILED)

P-VALUE - FRAGMENTS OF FEMUR WITH MAXIMUM LENGTH OF FEMUR (FML)

FRAGMENTS	FML (MALES)	FML (FEMALES)	FML (OVERALL)
VHD	0.000	0.000	0.000
VND	0.000	0.000	0.000
VHA	0.000	0.000	0.000
BCB	0.000	0.048	0.000
FDL	0.000	0.001	0.000
LCL	0.000	0.013	0.000
MCL	0.000	0.000	0.000

As a thumb rule, we shall consider correlation coefficient between 0.00 and 0.30 are considered weak, those between 0.300 and 0.700 are moderate and coefficients between +0.70 and 1.00 are considered high.

All the measurements showed positive degree of correlation. When correlation coefficients of individual measurements the maximum femoral length are determined in combined both male and female sex, all of them show good degree of association.

After separating them, we can see that individual measurements of the fragments of the male femora show better correlation than those of female.

In males, all the parameters show a high degree of correlation, except vertical diameter of femoral (VHD) which display moderate degree of correlation.

In males, the correlation ranged from 0.618 to 0.811.

Both epicondylar breadth (FDL) and medial condylar length (MCL) showed the highest correlation (0.811), while vertical diameter of head (VHD) showed the lowest correlation (0.618).

However, in females only bicondylar length (BCB) shows low degree of correlation, whereas all the remaining parameters show moderate degree of correlation.

In females, the correlation ranged between 0.627 for medial condylar length and 0.257 for bicondylar length.

In males, the measurements showing the degree of correlation with femoral length in descending order are epicondylar breadth (FDL), medial condylar length (MCL), upper breadth of femur (VHA), lateral condylar length (LCL), bicondylar length (BCB), vertical diameter of neck (VND) and vertical diameter of head (VHD).

In females, the measurements showing degree of correlation with femoral length (FML) in descending order are medial condylar length (MCL), upper breadth of femur (VHA), vertical diameter of head (VHD), vertical diameter of neck (VND), epicondylar breadth (FDL), lateral condylar length (LCL) and bicondylar length (BCB).

Table- 6 presents the slopes, intercepts and standard errors of estimates

Table-6

REGRESSION CONSTANTS FOR ESTIMATING FML FROM FEMUR FRAGMENTS

SEX	SLOPE (B)	INTERCEPT (A)	STANDARD ERROR OF ESTIMATE
PREDICTOR VARIABLE – VERTICAL DIAMETER OF HEAD VHD			
MALES	4.19	25.61	1.195
FEMALES	3.79	25.16	1.102
OVERALL	6.0	17.0	1.251
PREDICTOR VARIABLE – VERTICAL DIAMETER OF NECK VND			
MALES	3.25	34.30	1.072
FEMALES	3.89	29.40	1.138
OVERALL	6.26	23.89	1.492

PREDICTOR VARIABLE – UPPER NREADTH OF FEMUR VHA			
MALES	2.33	22.56	0.900
FEMALES	1.73	25.77	1.097
OVERALL	2.96	16.31	1.144
PREDICTOR VARIABLE – BICONDYLAR LENGTH BCB			
MALES	2.40	27.51	0.970
FEMALES	1.11	32.74	1.348
OVERALL	3.83	16.61	1.510
PREDICTOR VARIABLE – EPICONDYLAR BREADTH FDL			
MALES	3.99	13.10	0.888
FEMALES	1.84	27.30	1.270
OVERALL	3.88	13.84	1.185
SEX	**SLOPE (B)**	**INTERCEPT (A)**	**S.E.E.**
PREDICTOR VARIABLE – LATERAL CONDYLAR LENGTH LCL			
MALES	2.60	28.61	0.923
FEMALES	1.46	31.64	1.322
OVERALL	4.48	16.08	1.643
PREDICTOR VARIABLE – MEDIAL CONDYLAR LENGTH MCL			
MALES	2.30	30.34	0.889
FEMALES	3.42	21.86	1.087
OVERALL	3.92	19.71	1.234

For male, female or combined for estimation femoral length (FML). The values obtained are by linear regression analysis of the individual measurements with the FML which is shown from figure A - U.

Table 7 elaborates the regression equations that can be used to determine FML using independent variable. They are classified under male, female. The correlation co-efficient and the standard error of estimate of the equations are also mentioned.

Table- 7

EQUATIONS	CORRELATIONS	STANDARD ERROR OF ESTIMATE
MALES		
13.105+3.994(FDL)	0.658	0.888
30.340+2.303(MCL)	0.657	0.889
22.563+2.335(VHA)	0.649	0.900
28.611+2.603(LCL)	0.630	0.925
27.511+2.398(BCB)	0.593	0.970
34.302+3.255(VND)	0.503	1.072
25.606+4.187(VHD)	0.382	1.195
FEMALES		
21.860+3.425(MCL)	0.393	1.087
25.774+1.731(VHA)	0.382	1.097
25.163+3.787(VHD)	0.376	1.102
29.398+3.896(VND)	0.335	1.138
27.298+1.838(FDL)	0.171	1.270
31.638+1.458(LCL)	0.102	1.322
32.742+1.106(BCB)	0.066	1.348

The equations for males showed moderate to lower degree correlation.

In males, the correlations ranged between 0.658 of epicondylar breadth (FDL) and 0.382 of vertical diameter of head (VHD). The equation using FDL showed the highest correlation, while the equation using VHD showed the lowest.

In equation for females, the correlation is of moderate to lower degree, ranging from 0.393 of medial condylar length (MCL) and 0.066 of bicondylar breadth (BCB).

The MCL showed the highest correlation, while the BCB showed the lowest.

The standard error of estimate (SEE) ranged from 0.888 to 1.195 in males and in females, the SEE is between 1.087 and 1.348.

Table 8 elaborates the regression equations that can be used to determine FML, using combined measurements of different femoral fragment. They are classified under male, female. The correlation co-efficient and the standard error of estimate of the equations are also mentioned.

TABLE -8

EQUATIONS	CORRELATIONS	STANDARD ERROR OF ESTIMATE
MALES		
14.137+2.314(FDL)+1.291(VHA)	0.740	0.781
16.603+1.607(FDL)+0.963(VHA)+1.007(LCL)	0.776	0.732
18.193+1.849(FDL)+1.199(VHA)+1.249(LCL)-1.584(VHD)	0.796	0.704
19.977+1.219(FDL)+1.228(VHA)+1.034(LCL)-1.933(VHD)+0.815(BCB)	0.818	0.672
FEMALES		
19.999+2.420(VND)+2.462(MCL)+0.57(VHA)	0.491	1.013
20.117+2.552(VND)+2.360(MCL)-0.142(VHA)+0.315(LCL)	0.496	1.017
23.443+1.859(VND)+0.607(VHA)-1.048(BCB)-1.118(LCL)+3.664(MCL)	0.573	0.944

The equations for males showed higher degree correlation.

In equations for males, the correlations ranged between 0.740 and 0.818.

In equations for females, the correlation is of moderate degree, ranging from 0.491 to 0.573.

The standard error of estimate (SEE) ranged from 0.672 to 0.781 in males and in females, the SEE is between 0.944 and 1.013.

Table 9 elaborates the regression equations that can be used to determine FML, combining different fragment measurements of the femur, when the sex is in doubt. The correlation co-efficient and the standard error of estimate of the equations are also mentioned.

Table – 9

EQUATIONS FOR ESTIMATION OF MAXIMUM LENGTH OF FEMUR (WITH CORRELATION AND SEE) FROM FRAGMENTS OF FEMUR IN OVERALL DATA

EQUATIONS	CORRELATIONS	STANDARD ERROR OF ESTIMATE
16.307+2.961(VHA)	0.860	1.144
19.706+3.924(MCL)	0.837	1.234
13.841+3.884(FDL)	0.850	1.185
17.006+6.004(VHD)	0.833	1.251
23.894+6.264(VND)	0.762	1.492
16.612+3.828(BCB)	0.757	1.510
16.084+4.483(LCL)	0.712	1.643
16.647+1.773(MCL)+1.760(VHA)	0.890	1.021
14.975+1.279(VHA)+1.289(FDL)+1.157(MCL)	0.900	0.974

When individual measurements are considered, the equation using vertical diameter of head (VHA) showed the highest correlation (0.860), while the equation using lateral condylar length (LCL) showed the lowest (0.712).

The standard error of estimate range from 1.185 to 1.643.

When different fragments measurements are combined, the ranged from 0.890 to 0.900. The standard error of estimate SEE range from 0.974 to 1.021.

Table 10 elaborates the regression equations that can be used to determine FML, using only the measurements of the proximal segment of the femur (when only the upper segment of the femur is recovered). They are classified under male, female. The correlation co-efficient and the standard error of estimate of the equations are also mentioned.

Three measurements are present in the upper segment of the femora

- Upper breadth of the femur (VHA)
- Vertical diameter of the head(VHD)
- Vertical diameter of the neck.(VND)

Table – 10

EQUATIONS	CORRELATIONS	STANDARD ERROR OF ESTIMATE
SEX-MALE		
25.622-0.796(VHD)+1.393(VND)+1.925(VHA)	0.879	0.878
23.969+1.086(VND)+1.819(VHA)	0.673	0.876
SEX-FEMALE		
23.656+1.784(VHD)+1.343(VND)+0.707(VHA)	0.449	1.054
25.479+1.819(VND)+1.173(VHA)	0.415	1.076
OVERALL		
16.284+2.060(VHD)+0.782(VND)+1.713(VHA)	0.879	1.074

Equations derived for male samples presented a higher correlation (0.879 – 0.673) compared for that of females which exhibited moderate correlation (0.449- 0.415), whereas in overall samples it was highest (0.879).The standard error of estimate obtained for the estimation of FML ranged from 0.876 to 0.878 in males, 1.054 to 1.076 in females and 1.074 in overall samples.

Table 11 elaborates the regression equations that can be used to determine FML, using only the measurements of the distal segment of the femur (when only the distal femur is recovered). The correlation co-efficient and the standard error of estimate of the equations are also mentioned.

From the distal end of the femur, we can obtain

- epicondylar breadth,
- bicondylar breadth,
- medial condylar length and
- Lateral condylar length.

TABLE – 11

EQUATIONS FOR MALES	**CORRELATIONS**	**SEE**
19.526+0.596(BCB)+1.566(FDL)+0.928(LCL)+0.441(MCL)	0.756	0.771
18.013+0.659(BCB)+1.865(FDL)+1.162(LCL)	0.751	0.771

EQUATIONS FOR FEMALE		
23.777-1.163(BCB)+0.861(FDL)-1.178(LCL)+4.559(MCL)	0.452	1.061
24.750-0.765(BCB)-0.989(LCL)+4.809(MCL)	0.437	1.065
22.994-0.968(LCL)+4.220(MCL)	0.416	1.075
21.860+3.425(MCL)	0.393	1.087
EQUATIONS FOR OVERALL SAMPLES		
15.605-0.077(BCB)+2.242(FDL)-0.085(LCL)+1.960(MCL)	0.880	1.073
15.486-0.081(BCB)+2.237(FDL)+1.906(MCL)	0.880	1.068
15.435+2.195(FDL)+1.873(MCL)	0.880	1.064

Again equations derived for male samples presented a higher correlation (0.756 to 0.751) compared for the female sample (0.452 – 0.393), whereas in overall samples it was the highest (0.880)

The SEE for the estimation of maximum femoral length in males is 0.771, for females 1.061 to 1.087. In unknown sex samples it was 1.064 to 1.073.

We can compare the results of our study with that of four similar studies.

1. Steele DG and Mc Kern TW (1969)

2. Simmons et al (1990)

3. Bidmos M A (2008) - indigenous South Africans.

4. Bidmos M AM (2008) – South Africans of European Descent.

We are comparing the descriptive statistics and the correlation of the fragmentary measurement with the maximum femoral length between the present study and the above mentioned studies.

Comparison with Steele’s results (table- 12)

Steele s segment ‘a’ (1-2) is measured from the proximal point on the head of the femur to the mid-point of the lesser trochanter. It is comparable to our VHA in the size and the location of the fragment.

Table – 12

Comparison of mean and correlations between upper femoral breadth and Steele s segment

STEELES RESULTS	STEELE S SEGMENT I	
	X	CORRELATION
WHITE MALES	5.87	0.651
WHITE FEMALES	5.77	0.623
BLACK MALES	5.18	0.606
BLACK FEMALES	5.24	0.543
PRESENT STUDY	VHA	
	X	CORRELATION
MALES	9.5	0.806(**)
FEMALES	7.9	0.618(**)

The mean values of this segment are higher in our study than the steele's study in both sexes.

In our present study, males showed higher degree of correlation in contrast to steele's results where both the white and black males showed moderate degree of correlation.

The females showed moderate degree of correlation similar to white and black females in steele's study.

Table – 13 shows the **comparison of the descriptive statistics of present study with those of Simmons et al.**

The measurements common to our study and Simmons et al are VHD, VND, VHA, FDL and BCB.

Table – 13

STUDY	**VHD**		**VND**		**VHA**		**BCB**		**FDL**	
	X	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
WHITE MALES	4.83	0.32	3.31	.30	9.91	.59	7.78	.43	8.34	.45
BLACK MALES	4.76	.27	3.11	.26	9.90	.58	7.77	.46	8.3	.42
WHITE FEMALES	4.25	.25	2.93	.26	8.82	.52	6.84	.37	7.46	.35
BLACK FEMALES	4.19	.23	2.71	.25	8.90	.53	6.77	.39	7.40	0.4
MALES	4.6	0.2	3.2	0.3	9.5	0.5	7.2	0.5	8.0	0.3
FEMALES	3.8	0.2	2.6	0.2	7.9	0.5	6.1	0.3	6.6	0.3

The mean values of our male samples are lower than those of white males. Like wise with the exception of VND, our mean values are lower than that of black males. Similar trend is observed in females too. The mean values of our female samples are lower than those of both sexes of whites and blacks.

Table –14 shows the comparison of the descriptive statistics of present study with those of Bidmos.

The measurements common between our study and Bidmos study are VND, VHA, FDL, BCB, MCL, and LCL.

Table – 14

STUDY	**VND**		**VHA**		**FDL**		**BCB**		**LCL**		**MCL**	
	X	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
SAED MALES	3.40	.27	9.99	.56	8.07	.42	7.60	.33	6.52	.35	6.53	.37
IND SA MALES	3.23	.24	9.53	.60	7.87	.40	7.49	..46	6.47	.36	6.45	.37
SAED FEMALES	2.99	.28	9.01	.55	7.22	.39	6.74	.41	6.30	.35	5.95	.32
IND SA FEMALES	2.82	.25	8.57	.66	6.99	.50	6.66	.50	5.98	.44	5.78	.36
MALES	3.2	0.3	9.5	0.5	8.0	0.3	7.2	0.5	6.2	0.5	6.3	0.5
FEMALES	2.6	0.2	7.9	0.5	6.6	0.3	6.1	0.3	5.4	0.3	5.2	0.3

The mean values of our male samples are lower than those of south African males of European Descent. The mean values of our male samples except FDL are lower than those of Indigenous South Africans

The mean values of our female samples are lower than those of SAED females. The mean values of our female samples are lower than those of indigenous South Africans.

Table – 15 shows the correlation coefficients of the femur in the present study and those of Simmons et al.

Table – 15

STUDY		VHD	VND	VHA	BCB	FDL
SIMMONS ET AL	WHITE	0.526	0.384	0.606	0.541	0.521
	BLACK	0.454	0.315	0.592	0.440	0.465
	WHITE	0.596	0.409	0.632	0.445	0.537
	BLACK	0.585	0.422	0.513	0.345	0.415
PRESENT STUDY	MALES	0.618(**)	0.709(**)	0.806(**)	0.770(**)	0.811(**)
	FEMALES	0.613(**)	0.579(**)	0.618(**)	0.257(*)	0.414(**)

In Simmons study, all the measurements of both males and females showed moderate degree of correlation.

In our present study, all the parameters of males show a high degree of correlation, except VHD which display moderate degree of correlation.

However, in females only BCB shows low degree of correlation, whereas all the remaining parameters show moderate degree of correlation.

DISCUSSION

Discussion

Intact long bones of the upper and lower extremities have been used in the derivation of regression equations for the estimation of stature in different population groups. These bones are sometimes presented to forensic anthropologists in different states of fragmentation thereby making the derived equations unusable. This has necessitated the need to assess the usefulness of measurements of fragments of long bones (e.g. femur).

In an attempt to derive equations for stature estimation from femur fragments, Simmons et al. reported a difficulty in reproducing the measurements as suggested by Steele and McKern. As a result, Simmons et al used eight standard measurements of the femur namely (i) vertical diameter of femoral head VHD, (ii) Vertical diameter of the femoral neck VND, (iii)Upper breadth of the femur UEpL or VHA, (iv) Transverse diameter of the mid- shaft WSD, (v)Bicondylar breadth BCB, (vi)Epicondylar breadth EpB or FDL, (vii)Medial condylar height MCH, (viii)Lateral condylar height LCH in the estimation of maximum femoral length of Americans.

Four of the above mentioned measurements (VND, UEpl, BCB & EpB) and two other measurements (MCL & LCL) were used by MA Bidmos to calculate the stature and maximum femoral length in indigenous South African population and South African population of European Descent.

In the present study,120 adult femora were collected from the unidentified and unclaimed bodies coming for postmortem in the Institute of Forensic Medicine (60 males and 60 females).

Five of the measurements (VHD, VND, VHA, BCB and FDL) of Simmons et al study were used in this study because of the ease with which they could be reproduced. In addition to these, two other measurements medial condylar length (MCL) and lateral conylar length (LCL) were selected because of their high coefficient of reproducibility.

Using osteometric board and vernier calipers, measurements were taken.

The data were statistically analyzed using SPSS software.

Table- 1 shows the FML, VHD, VHA, VND, FDL, BCB, MCL, LCL values of 120 femora.

The minimum, maximum, mean and the standard deviation of all the measurements were taken from them.

Table 3 and table 4 show the descriptive statistics of the male and female femoral measurements respectively.

We can see that male consistently show higher mean value in maximum femoral length compared with females. It is in support of previous studies [14, 20, 22 and 23].

In males, the maximum length of femur ranged from 41.2 cm to 47.8 cm, with mean of 44.9 cm.

In females, the maximum length of femur ranged from 36.4 cm to 42.6 cm, with mean of 39.5 cm.

This result is also similar to the results reported in previous studies by Pearson & Bell (1917 – 1919).

The mean values of bicondylar length (BCB) and vertical head diameter (VHD) are lower than the values as reported in previous studies. Pearson & Bell (1917 – 1919) [7] & Reddy KSN [26].

Males also show higher mean values for all fragmentary measurements compared to females, emphasizing the sexual dimorphism of these femoral dimensions. Thus it is possible to determine the sex of the femur by the fragmentary measurements. This was also reported by Steyn and Iscan in their study of South African population.

Correlation is a measure of association between two variables in our case; it is the strength of association of the maximum femoral length with its fragments.

Correlation between the measurements of the fragments of the femur with its maximum length (FML) is scripted in table – 5. They are described under males, females.

All the measurements in our study show positive correlation with the FML.

When correlation coefficients of individual measurements the maximum femoral length are determined in combined both male and female sex, all of them show higher degree of association.

The proximal fragment VHA showed the highest correlation 0.927 and the second best is the distal fragment, epicondylar length FDL with 0.922.

After separating the data into males and females, females showed lower correlation coefficients compared to males.

In both sexes, the distal fragments correlate well with the femoral length.

Measurements of the distal fragments' epicondylar breadth (FDL) and medial condylar length (MCL) consistently showed the best correlation with FML in males.

Again in females, the distal fragment medial condylar length (MCL) showed the best correlation with FML.

The moderate to high degree of correlations obtained in the present study confirms the usefulness of fragments of femur in the estimation of maximum length of femur.

This proves the usefulness of fragmentary measurements for deriving regression equations for the femoral length.

Therefore it is prudent to derive simple linear regression (y = a + b x) by univariate regression analysis against the individual measurements to calculate FML from anyone of these markers.

Table – 6 shows the regression constants for estimating maximum length of femur from its fragmentary measures, based on its sex.

In the simple linear regression equations (y = a + b x) , y is the FML, a is the intercept, b is the slope, x is the measure of the predictor variable.

Like wise, when a segment of femur is recovered, which may be either proximal segment or the distal segment; we can determine the maximum length of femur by the multivariate regression analysis of their respective measurements.

Table 7 elaborates the regression equations that can be used to determine FML using independent variable, which are classified under male, female.

The regression equations from the distal fragments epicondylar breadth (FDL) and medial condylar length (MCL) fragment showed the highest correlation 0.658 and 0.657 respectively in males, and the medial condylar length (MCL) in females (0.393).

Thus **when small fragments of femur are available for the medico legal investigation, the maximum length of femur can be best calculated from the metric evaluation of epicondylar breadth (FDL) and medial condylar length (MCL) fragment in males.**

- **13.105+3.994(FDL) ± 0.888**
- **30.340+2.303(MCL) ± 0.889**

In females, the maximum length of femur can be best calculated from the metric evaluation of medial condylar length (MCL) fragment.

- **21.860+3.425(MCL) ± 1.087**

When the sex is unknown or in doubt, the maximum length of femur can be best calculated from the metric evaluation of the proximal fragment VHA and the distal fragment, epicondylar length FDL.

- **16.307+2.961(VHA) ± 1.144**
- **13.841+3.884(FDL) ± 1.185**

Table 8 elaborates the regression equations that can be used to determine FML, using combined measurements of the fragments of femur, which are classified under male, female.

Table 9 elaborates the regression equations that can be used to determine FML, using combined measurements of the femur, when the sex is in doubt.

The regression formulae using combination of fragmentary length show much better correlation with femoral length than using single fragments.

The overall samples show high degree of correlation (0.890 to 0.900) and the SEE range from 1.021 to 1.643.

While the males show high degree of correlation (0.740 – 0810) and the SEE range from 0.672 to 0.781, the females show moderate degree of correlation ranging from 0.491 to 0.573.The SEE is between 0.944 and 1.013.

The best equation to calculate the maximum length of femur using measurements of different fragments in males is

- **19.977+1.219(FDL) + 1.228(VHA) + 1.034(LCL) - 1.933(VHD) + 0.815(BCB) ± 0.672**

The best equation to calculate the maximum length of femur using measurements of different fragments in females is

- **23.443+1.859(VND)+0.607(VHA)-1.048(BCB)-1.118(LCL)+3.664(MCL) ± 0.944**

When the sex is not known, the maximum length of femur can be obtained from the equation

- **14.975+1.279(VHA)+1.289(FDL)+1.157(MCL) ± 0.974**

Table 10 elaborates the regression equations that can be used to determine FML, combining the fragmentary measurements of the proximal segment of the femur.

In cases where only proximal end of the femur is recovered, only three measurements are present

- Upper breadth of the femur (VHA)
- Vertical diameter of the head(VHD)
- Vertical diameter of the neck.(VND)

Thus, if only the proximal segments are considered, the regression equations

- **25.622-0.796(VHD)+1.393(VND)+1.925(VHA) ± 0.878 (for males)**
- **23.656+1.784(VHD)+1.343(VND)+0.707(VHA) ± 1.054 (for females) and**
- **16.284+2.060(VHD)+0.782(VND)+1.713(VHA) ± 1.074 (for unknown sex) showed the best correlations.**

When only the upper segment of the femur is recovered, the FML can be best calculated from the above equations.

Table 11 elaborates the regression equations that can be used to determine FML, combining the measurements of the distal segment of the femur.

From the distal end of the femur, we can obtain

- epicondylar breadth,
- bicondylar breadth,
- medial condylar length and
- Lateral condylar length.

The equations

- **19.526+0.596(BCB)+1.566(FDL)+0.928(LCL)+0.441(MCL) ± 0.771 for males**

- **23.777-1.163(BCB)+0.861(FDL)-1.178(LCL)+4.559(MCL) ± 1.061 for females and**

- **15.435+2.195(FDL)+1.873(MCL) ± 1.064 for unknown sex showed the best correlations.**

Thus if only the distal segment of femur is recovered, the FML can be best calculated from the above equations.

The calculated maximum femoral length can be used to estimate the stature of the individual by the regression equations, tables or the multiplication factors already established by the various studies.

We can compare the results of our study with that of four similar studies.

1. Steele DG and Mc Kern TW (1969)
2. Simmons et al (1990)
3. Bidmos M A (2008)- Indigenous South Africans.
4. Bidmos M AM (2008) – South Africans of European Descent.

We are comparing the descriptive statistics and the correlation of the fragmentary measurement with the maximum femoral length between the present study and the above mentioned studies.

Comparison with Steele s results (table- 12)

Steele s segment ‘a’ (1-2) is measured from the proximal point on the head of the femur to the mid-point of the lesser trochanter. It is similar to our VHA in the size and the location of the fragment.

Table – 19 shows the comparison of mean and correlations between upper femoral breadth and Steele s segment

We can see that our study shows superior correlation when compared with Steele data in white males, black males, and black females. The correlation is lower than in white females. Thus it can be suggested that our methodology is better than Steele's approach.

Comparison with Simmons et al results (table- 13)

Table – 20 shows the comparison of the descriptive statistics of present study with those of Simmons et al.

The measurements common to our study and Simmons et al are VHD, VND, VHA, FDL and BCB.

The mean values of our male samples are lower than those of white males. Like wise with the exception of VND, our mean values are lower than that of black males. Similar trend is observed in females too. The mean values of our female samples are lower than those of both sexes of whites and blacks.

We can note that since mean values of most of the measures in Simmons study are more than that of our study, people from Indian origin are shorter than the population sample considered by them.

<u>Comparison with Bidmos results (table- 14)</u>

Table –21 shows the comparison of the descriptive statistics of present study with those of Bidmos.

The measurements common between our study and Bidmos study are VND, VHA, FDL, BCB, MCL, and LCL.

The mean values of our male samples are lower than those of south African males of European Descent.(SAED)

The mean values of our male samples except FDL are lower than those of indigenous South Africans.

The mean values of our female samples are lower than those of SAED females.

The mean values of our female samples are lower than those of indigenous South Africans.

Since mean values of most of the measures in Bidmos study are more than that of our study, people from Indian origin are shorter than the South African population sample considered by them.

Table – 22 shows the correlation coefficients of the femur in the present study and those of Simmons et al.

In males all the five measurements, the correlation coefficients reported in this study is higher than those of Simmons et al

In females, VHD and VND showed better correlation than those in Simmons et al. However correlation of BCB and FDL in our study is lower than that in Simmons et al.

VHA in our study shows higher correlation than that in black female group, but it was lower than that in white female group of Simmons et al.

The general trend that measurements in this study showed a higher correlation compared with corresponding measurements of Simmons et al in male sex indicating that measurements in this study have a higher predictive efficiency compared to those used by Simmons et al.

In both white and black males, the proximal femoral segment upper breadth of femur (VHA) showed the best correlation to femoral length (FML) in Simmons study, whereas the distal femoral segment epicondylar breadth (FDL) in males showed the best correlation to femoral length (FML) in our study.

In Simmons study, the proximal segment upper breadth of femur (VHA) showed the best correlation to femoral length (FML) in white females and vertical diameter of head (VHD) showed the best correlation to femoral length (FML) in black females. In our study also upper breadth of femur (VHA) showed the best correlation and vertical diameter of head (VHD) showed the second best correlation.

Table – 23 shows the correlation coefficients of comparable measurements of the femur in the present study and those of Bidmos M.

In males all the six measurements, the correlation reported in this study is higher than that of Bidmos M AM.

In females, with the exception of vertical diameter of neck (VND) and medial condylar length (MCL), all the other four measurements, the correlation described in our study is lower than that of Bidmos.

The measurements in this study showed a higher correlation compared with corresponding measurements of Bidmos in male sex indicating that measurements in this study have a higher predictive efficiency compared to those used by Bidmos.

Correlation of vertical diameter of neck (VND) in our study is better than that of South African of European females but lower in Indigenous South Africans.

Correlation of medial condylar length (MCL) in our study is better than that of Indigenous South Africans but lower in South African of European Females.

In our present study, measurements of the distal end fragments of femur consistently showed the best correlation with femoral length (FML) in both males and females.

In males, both the epicondylar length (FDL) and the medial condylar length (MCL) displayed the highest correlation. This in contrast to the observations made by Bidmos, where the upper breadth of femur (VHA), one of the measurements on the proximal aspect of the femur, showed highest correlation for femoral length (FML) in both SAED and Indigenous South African males.

In females, the measurements of the distal fragment epicondylar length (FDL) showed the best correlation which is the similar to the observation made by Bidmos in SAED females, but in contrast to the observation in Indigenous South African females where the proximal segment upper breadth of femur (VHA) showed the best correlation.

CONCLUSION

Conclusion

1. The mean maximum femoral length in males was observed to be more than females in males and was 44.9 cms, whereas that of females was 39.5 cms.
2. The mean values of all fragmentary measurements in males were found to be higher than that of females. Therefore, sex determination is possible from the fragmentary remains of the femur.
3. All the fragmentary measurements in our study showed positive correlations with the femoral length (FML). Therefore the maximum femoral length can be estimated from fragmentary remains of the femur.
4. Among all the fragments in males, the epicondylar length (FDL) and medial condylar length (MCL) of the distal fragments consistently showed the best correlation with the maximum femoral length. The vertical diameter of femoral head (VHD) of the proximal fragments showed the least correlation with the maximum femoral length.

5. In females also, the medial condylar length (MCL) of the distal fragments consistently showed the best correlation with the maximum femoral length. But, the bicondylar length (BCB) showed the least correlation with the maximum femoral length.
6. When the sex of the femur is not determined, the upper breadth of femur (VHA) of the proximal segment showed the best correlation with the maximum femoral length. But, the lateral condylar length (LCL) showed the least correlation with the maximum femoral length.
7. In males, the maximum length of femur can be best calculated from the metric evaluation of epicondylar breadth (FDL) and medial condylar length (MCL) fragments.

In males, the following equations can be used to calculate the maximum length of femur

- $13.105+3.994(FDL) \pm 0.888$
- $30.340+2.303(MCL) \pm 0.889$

8. In females, the maximum length of femur can be best calculated from the metric evaluation of medial condylar length (MCL) fragment.

In females, the following equation can be used to calculate the maximum length of femur

- 21.860+3.425(MCL) ± 1.087

9. When the sex is unknown or in doubt, the maximum length of femur can be best calculated from the metric evaluation of the proximal fragment (VHA) and the distal fragment, epicondylar length (FDL). Therefore when the sex is in doubt or unknown, the following equation can be used to calculate the maximum length of femur

- 16.307+2.961(VHA) ± 1.144
- 13.841+3.884(FDL) ± 1.185

10. The regression formulae using combination of fragmentary length showed much better correlation with maximum femoral length than using individual fragments.

The best equation to calculate the maximum length of femur in males is

- 19.977+1.219(FDL) + 1.228(VHA) + 1.034(LCL) - 1.933(VHD) + 0.815(BCB) ± 0.672

The best equation to calculate the maximum length of femur in females is

- 23.443+1.859(VND)+0.607(VHA)-1.048(BCB)-1.118(LCL)+3.664(MCL) $\pm$ 0.944
- When the sex is not known, maximum length of femur can be calculated using the equation 14.975+1.279(VHA)+1.289(FDL)+1.157(MCL) $\pm$ 0.974

11. Since the sample size is small, more authoritative equation can be obtained by analyzing more samples.

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KEY WORDS

FML: MAXIMUM FEMORAL LENGTH

VHD: VERTICAL DIAMETER OF HEAD

VND: VERTICAL DIAMETER OF NECK

VHA: UPPER BREADTH OF FEMUR

FDL: EPICONDYLAR BREADTH

BCB: BICONDYLAR BREADTH

MCL: MEDIAL CONDYLAR LENGTH

LCL: LATERAL CONDYLAR LENGTH

UEpL: UPPER EPICONDYLAR LENGTH

ISA: INDIGENOUS SOUTHAFRICANS

SAED: SOUTHAFRICAN POPULATION OF EUROPEAN DESCENT